



An updated analysis on the trends and variability of the tropical width inferred from GPS RO, reanalyses, and climate models

Chi O. Ao¹, Olga P. Verkhoglyadova¹, Thomas
Birner², and Nicholas A. Davis²

¹ Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA

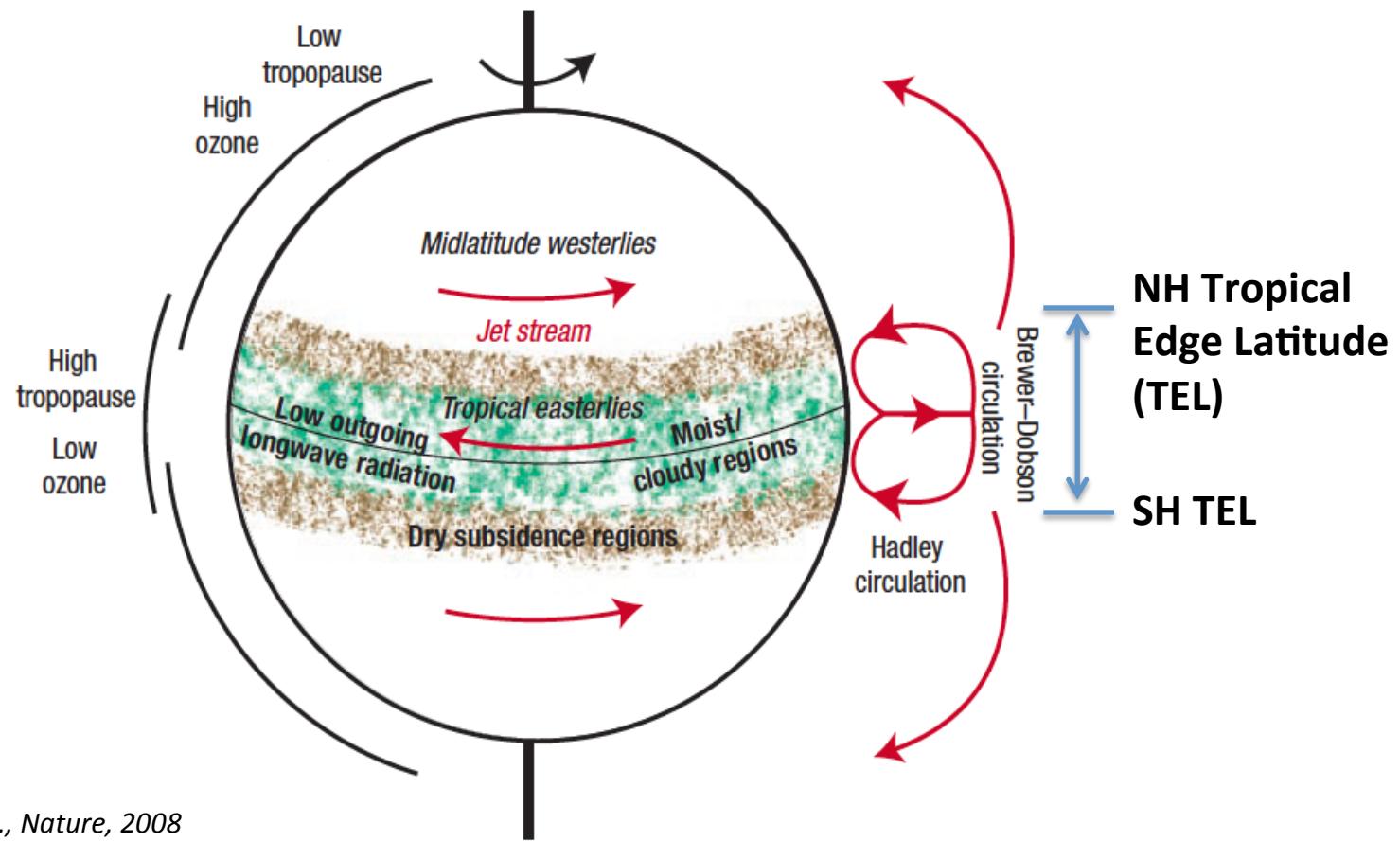
² Department of Atmospheric Science, Colorado State University, Fort Collins, CO, USA

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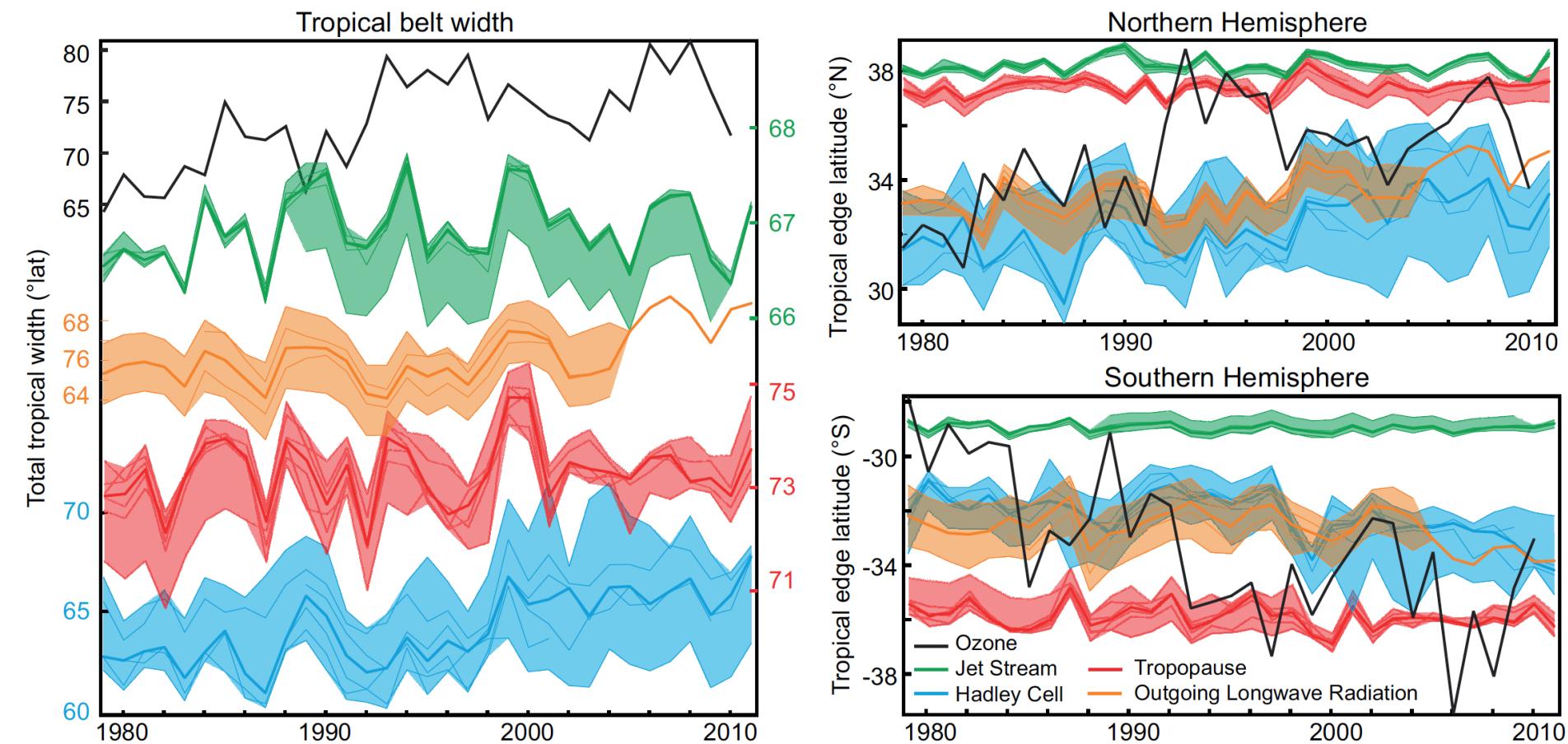
Overview

- How did and how will atmospheric circulation pattern change under global warming?
- Existing observations showed evidence in the widening of the tropical belt since 1979. GCMs also simulated widening but at a much lower rate [Johanson and Fu, 2009].
- Even a small shift of the tropical edges can have significant societal impact.
- RO can provide key observational constraints.

Tropical width = Latitude extent of Hadley Cells

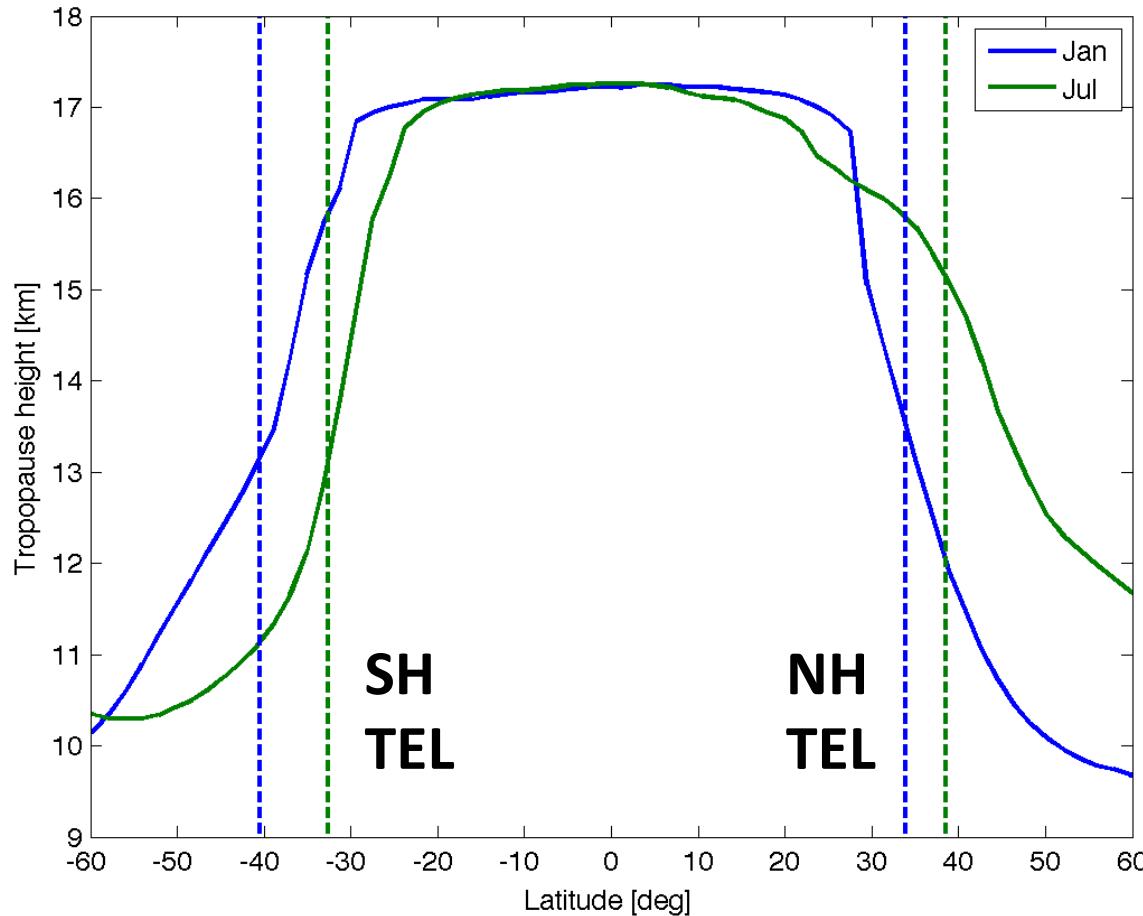


Seidel et al., Nature, 2008



IPCC AR5, 2013

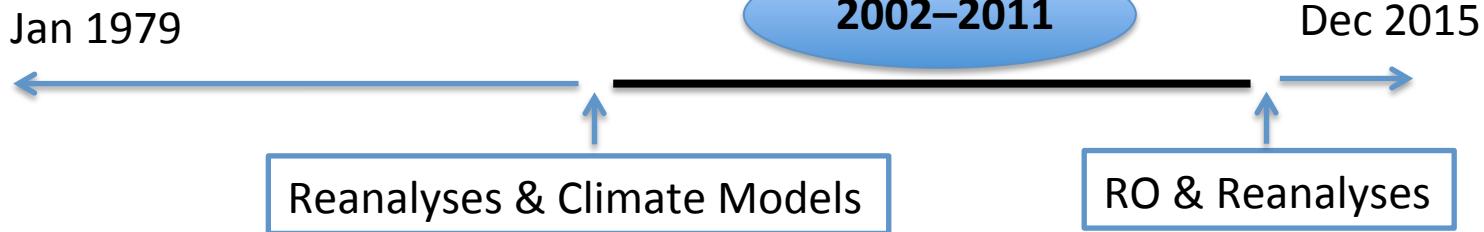
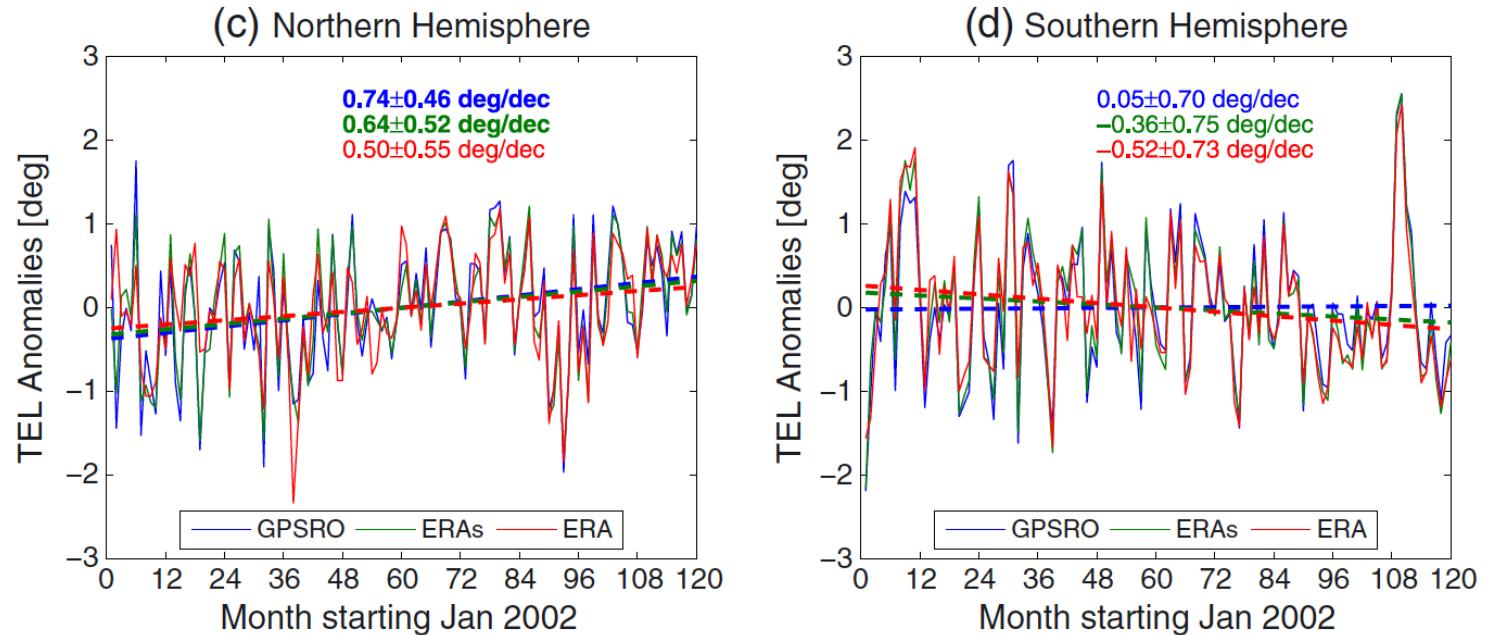
A Tropopause-Based Metric



$$\phi_{TEL} = \left[\sum_{\phi=15^\circ}^{60^\circ} \phi \frac{\partial Z_{LRT}}{\partial \phi} \cos \phi \right] / \left[\sum_{\phi=15^\circ}^{60^\circ} \frac{\partial Z_{LRT}}{\partial \phi} \cos \phi \right]$$

[Davis and Rosenlof, 2012]

Ao and Hajj, GRL, 2013: Trends between RO & ERA-interim

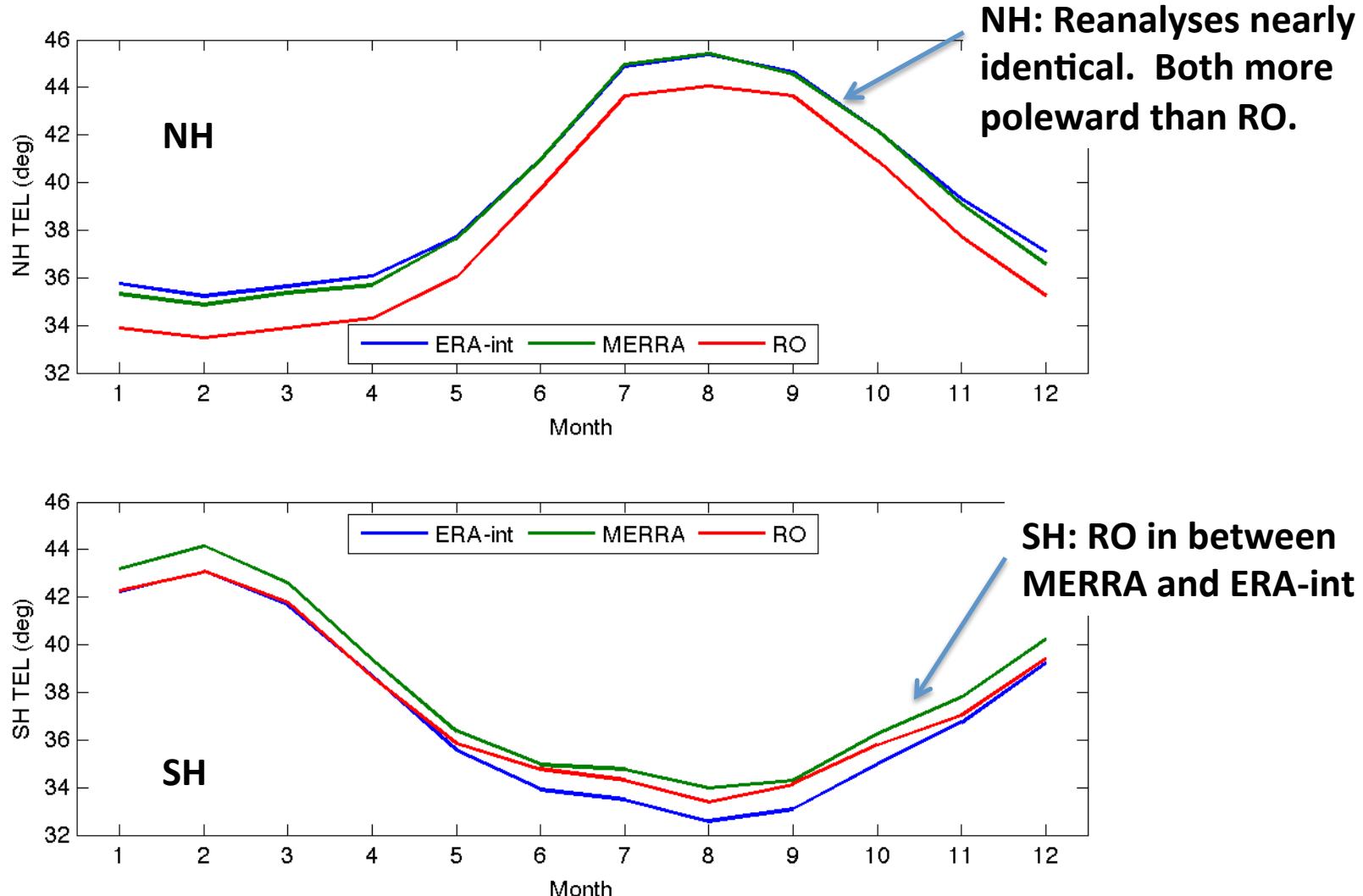


This work: Extend the datasets to longer periods and include additional analysis of seasonal and interannual variabilities [Davis and Birner, 2013].

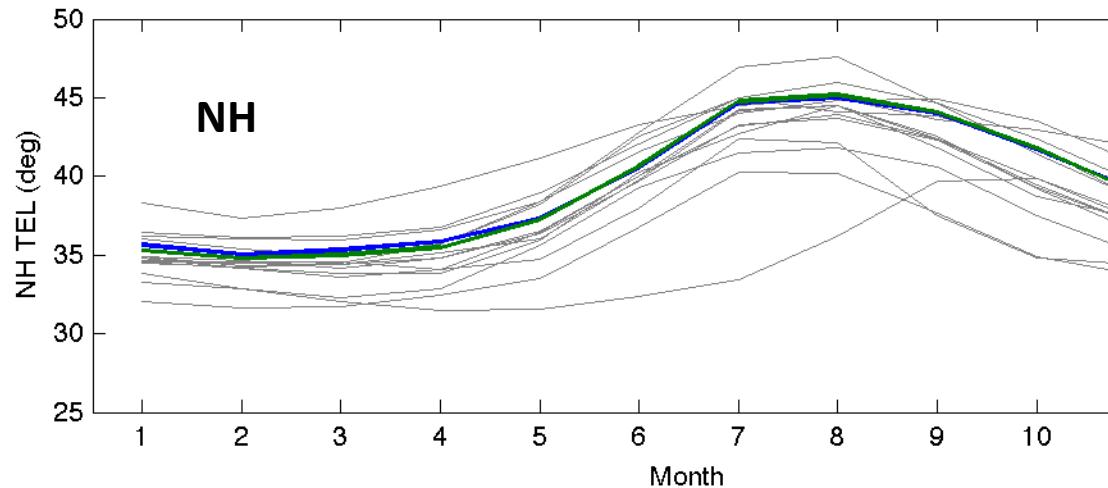
Datasets

- RO: CHAMP & COSMIC (2002–2015)
- Reanalyses (1979–2015)
 - ECMWF Reanalysis Interim (ERA-int)
 - Modern Era Retrospective-analysis for Research and Applications (MERRA)
- Climate models (~ 1960–2005)
 - Chemistry-Climate Model VALIDation (CCMVAL-2) REF-B1 (historical forcings, observed SST) [14 models]
- Lapse-rate tropopause heights calculated from monthly zonal mean temperature & geopotential height.

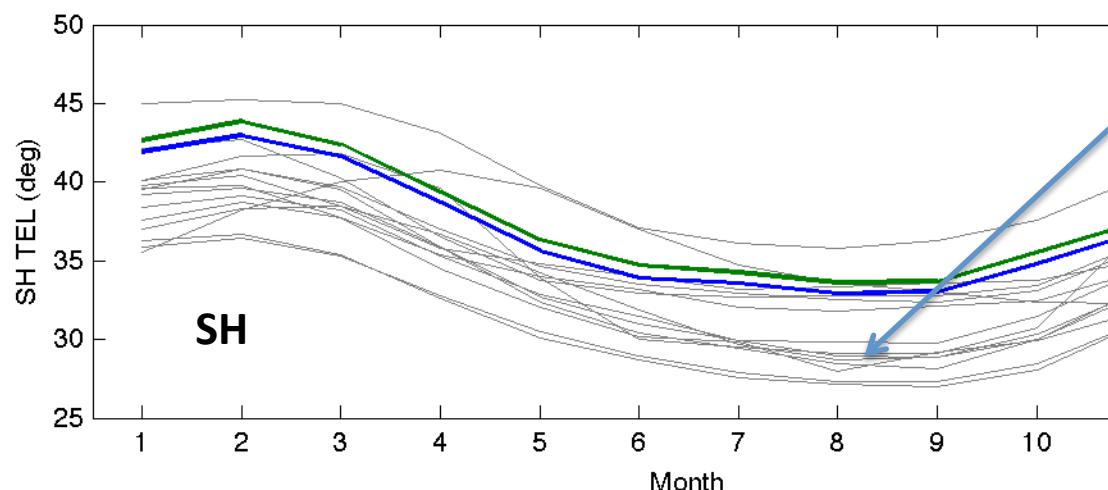
Seasonal Cycle (RO vs Reanalyses)



Seasonal Cycle (Reanalyses vs Models)

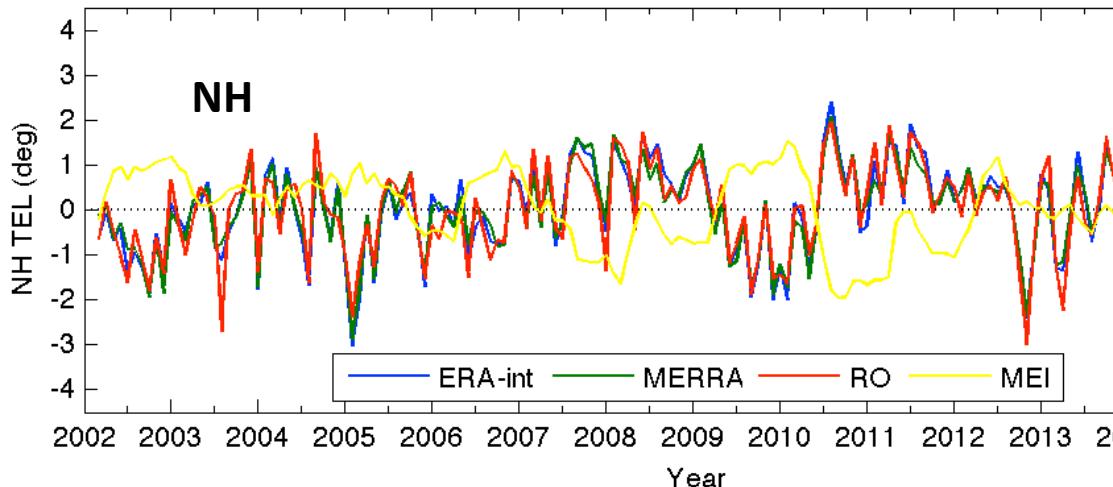


Models reproduce
the seasonal cycles
reasonably well.

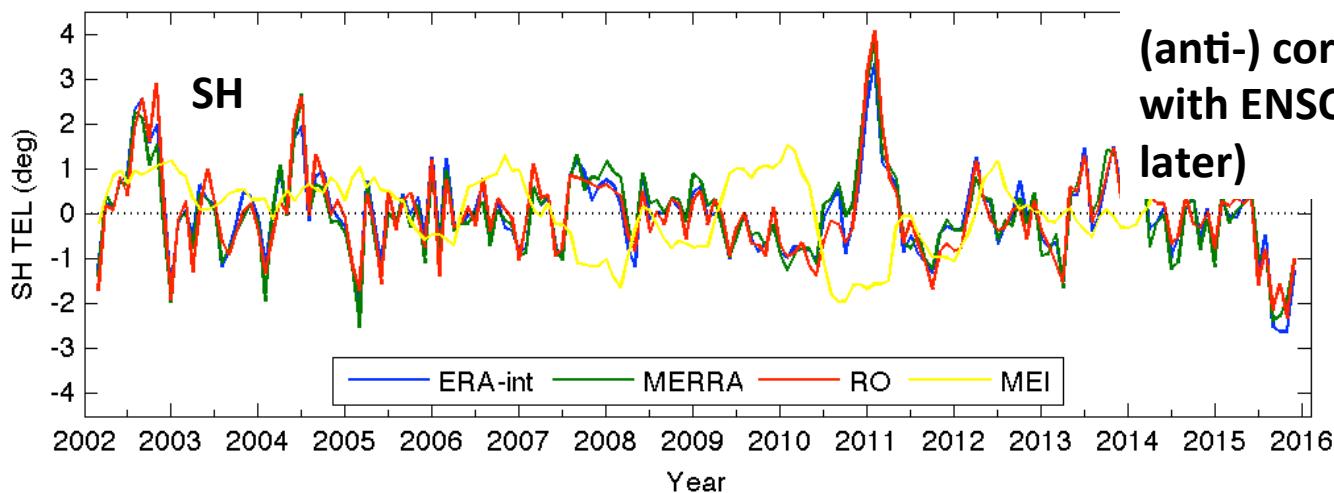


SH: Models more
equatorward.
Larger contractions
during winter.

Monthly Anomalies (2002–2015)

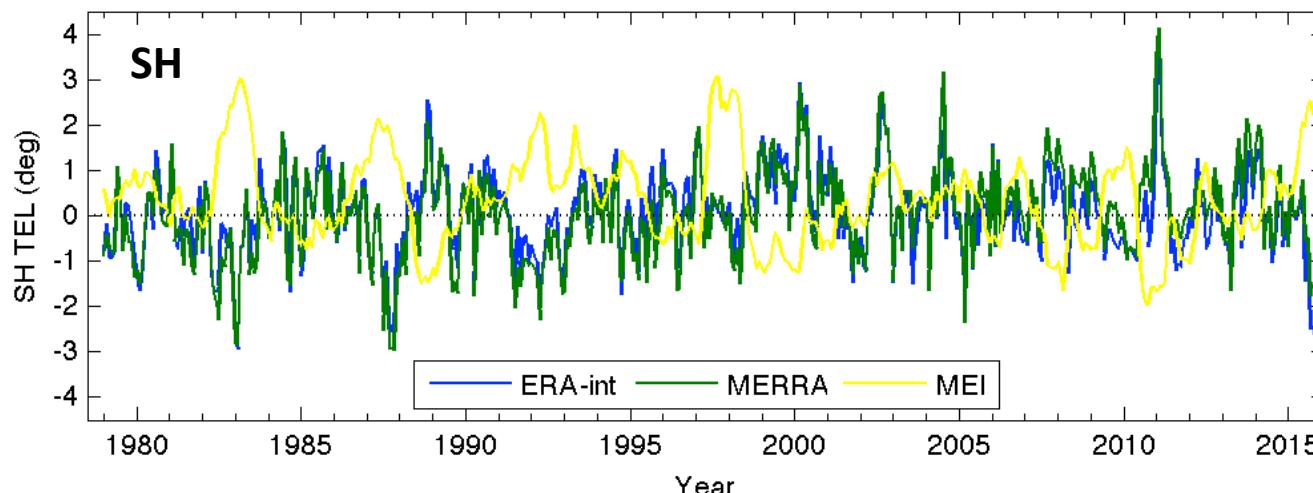
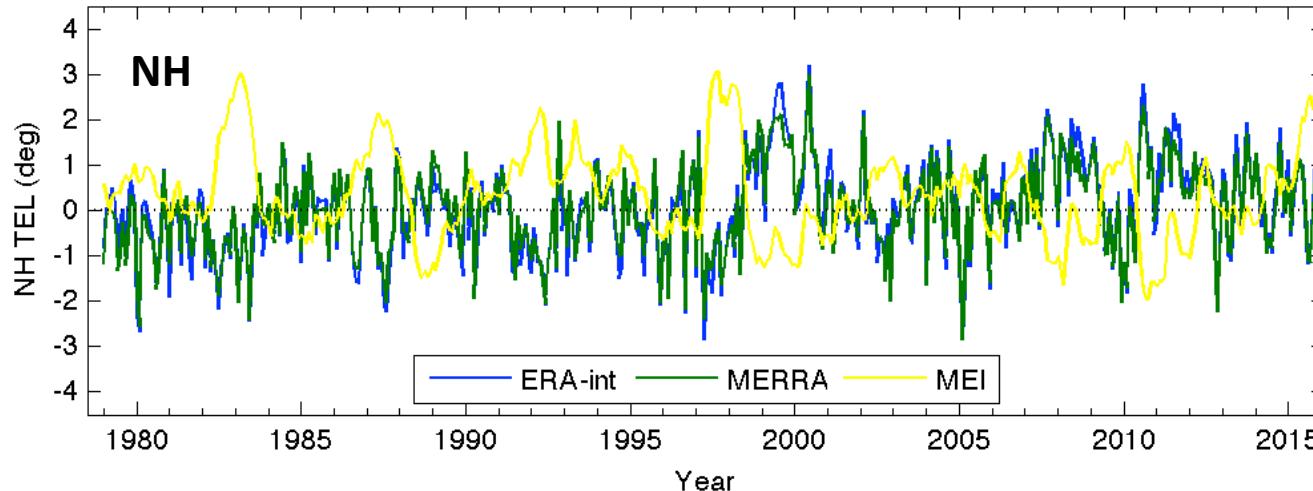


**Good agreement
between RO &
reanalyses**

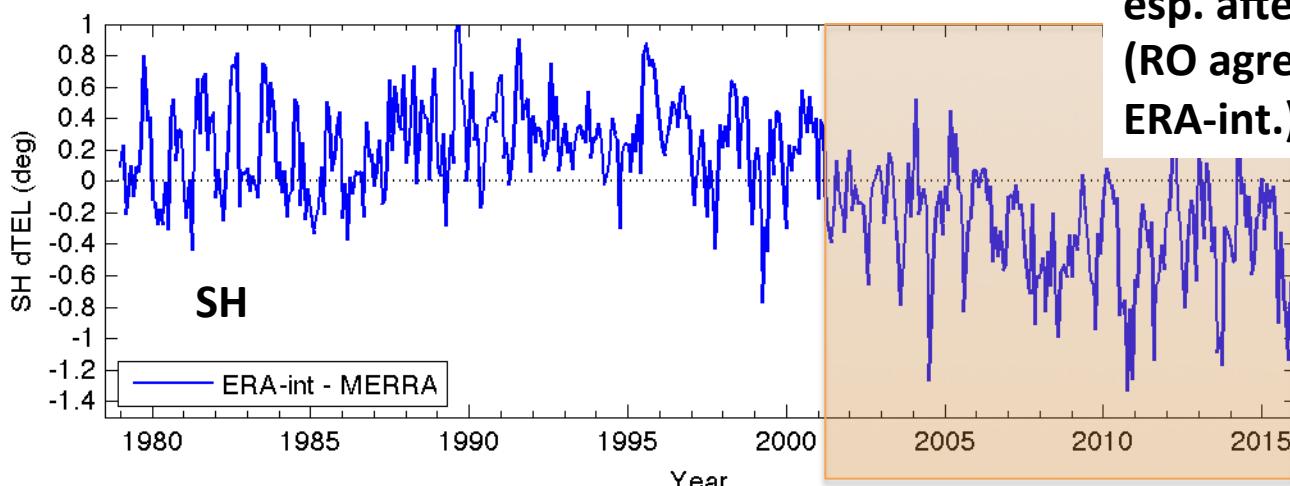
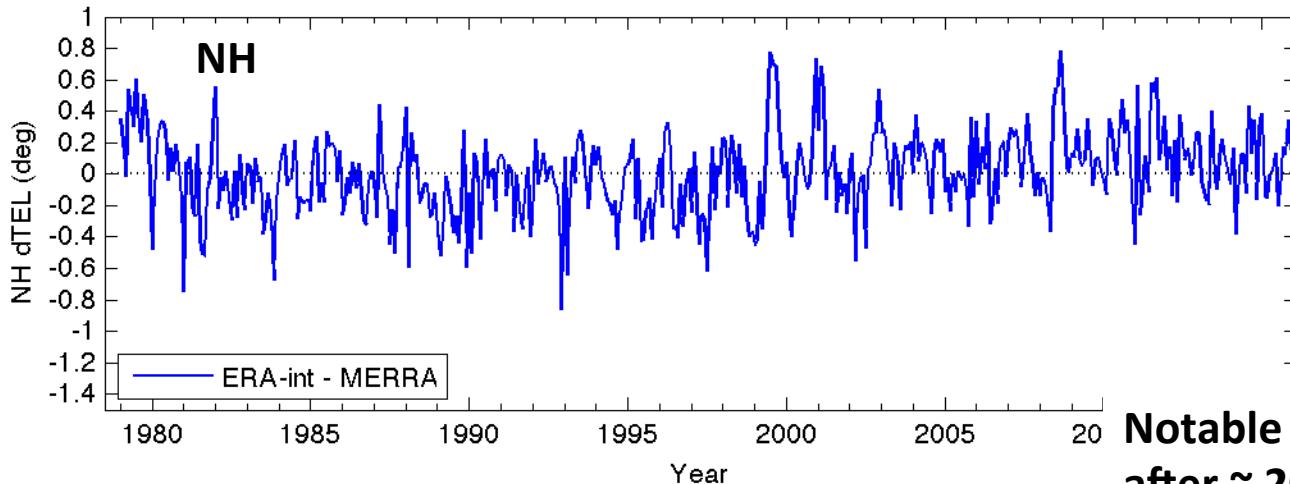


**(anti-) correlation
with ENSO (more
later)**

Monthly Anomalies (1979–2015)

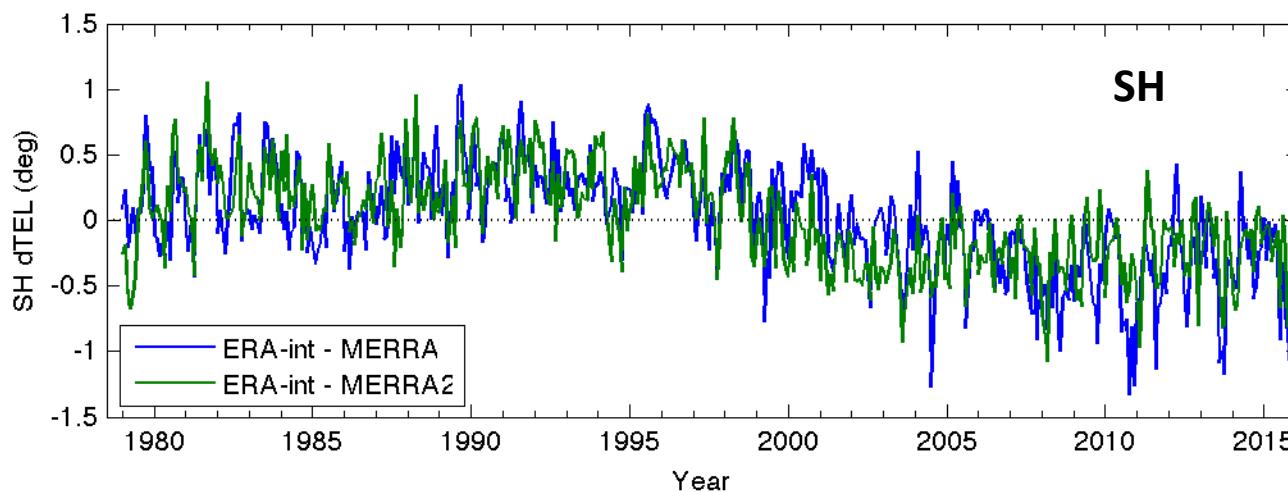
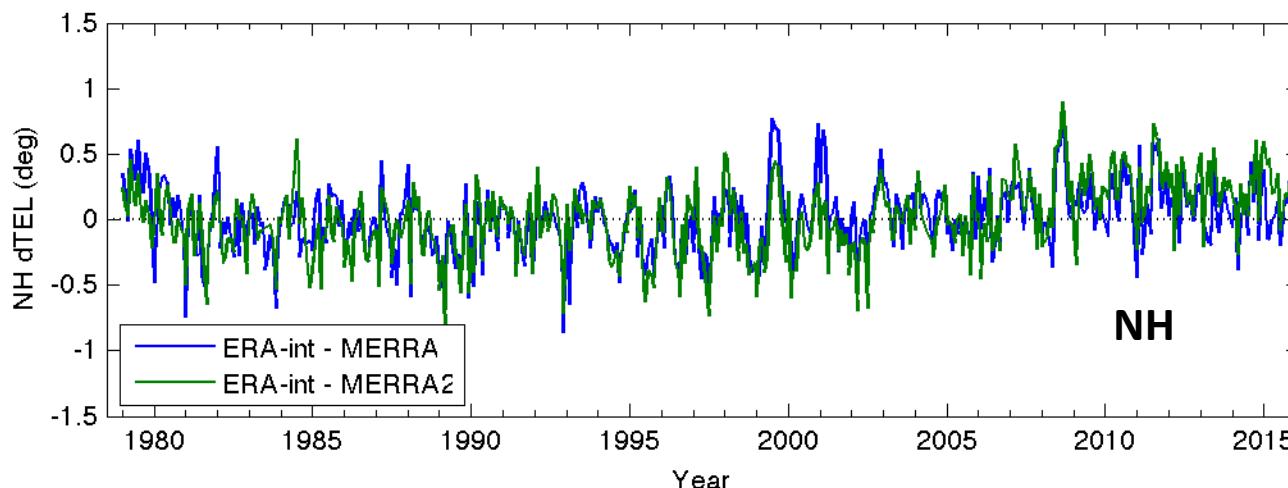


Reanalyses Difference

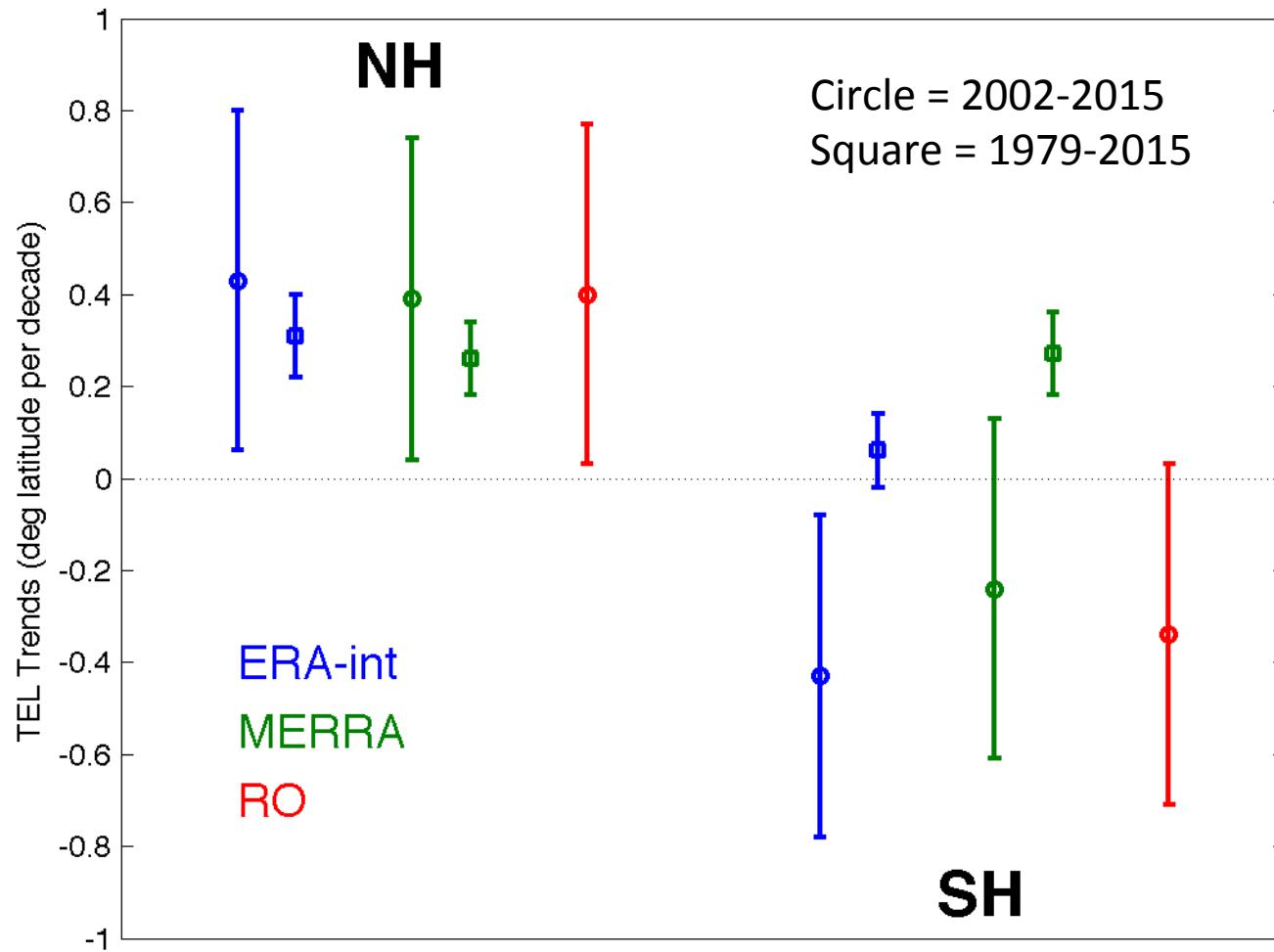


**Notable shift in SH
after ~ 2001 and
esp. after ~ 2006
(RO agrees with
ERA-int.)**

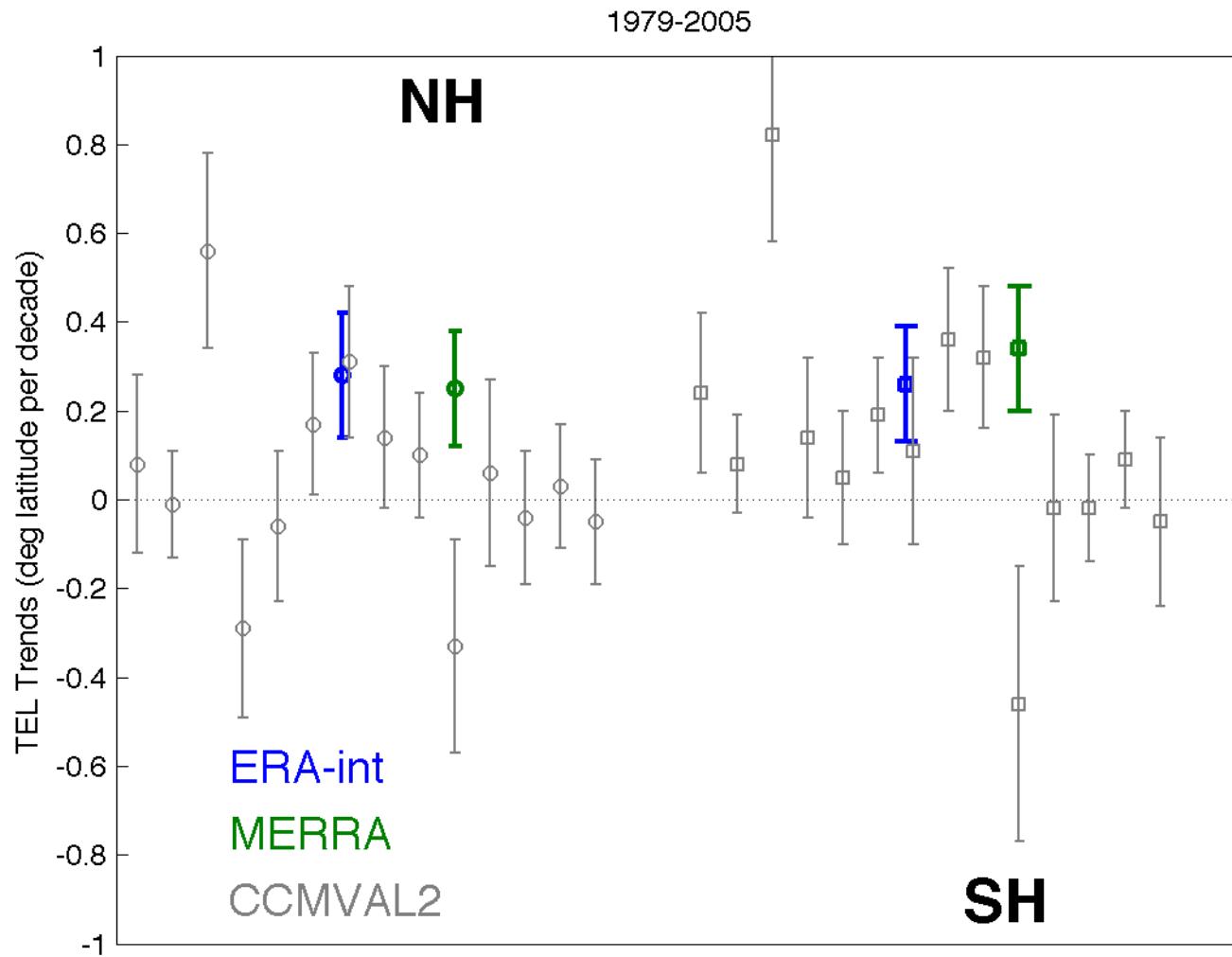
MERRA2



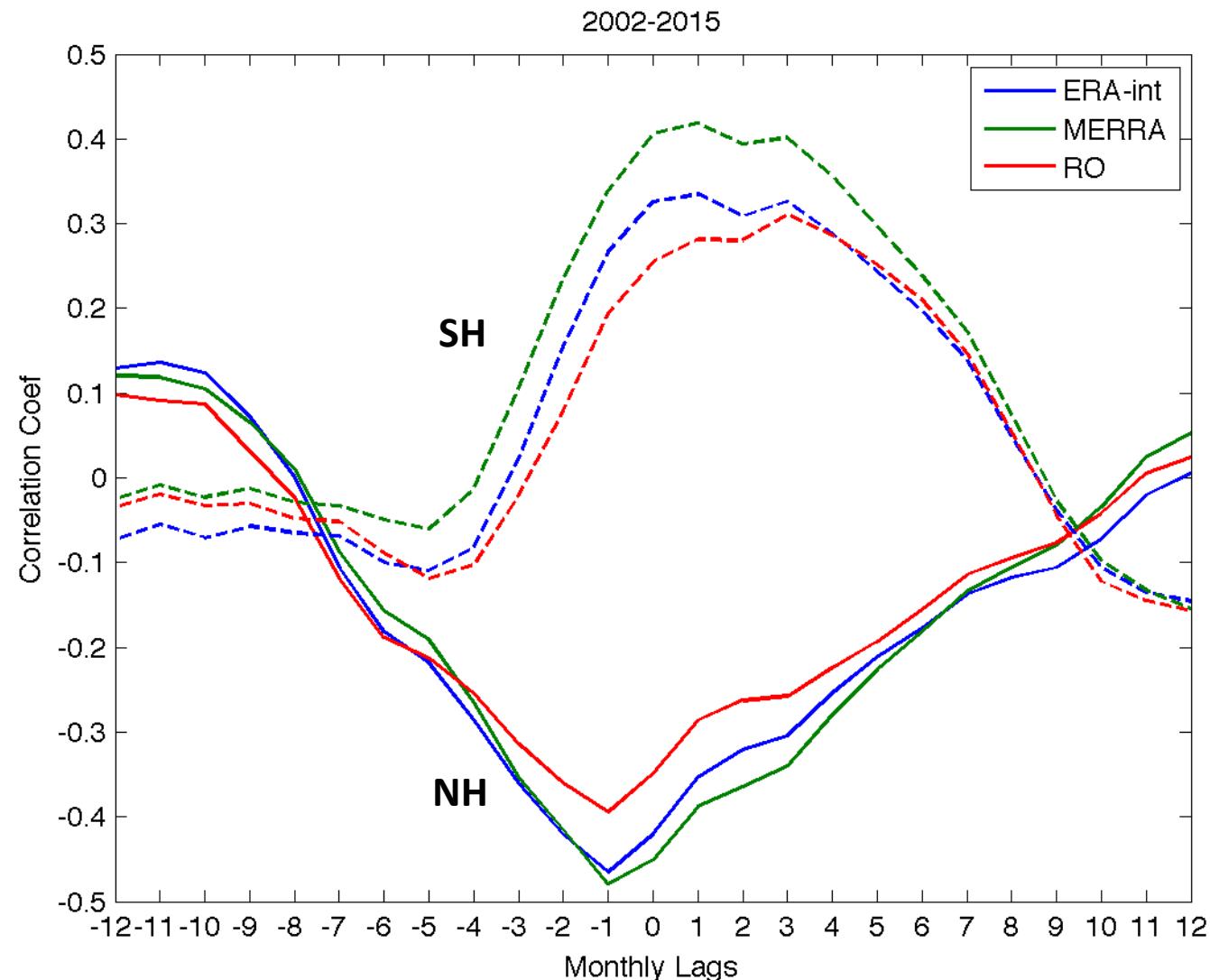
Recent Trends (RO & Reanalyses)



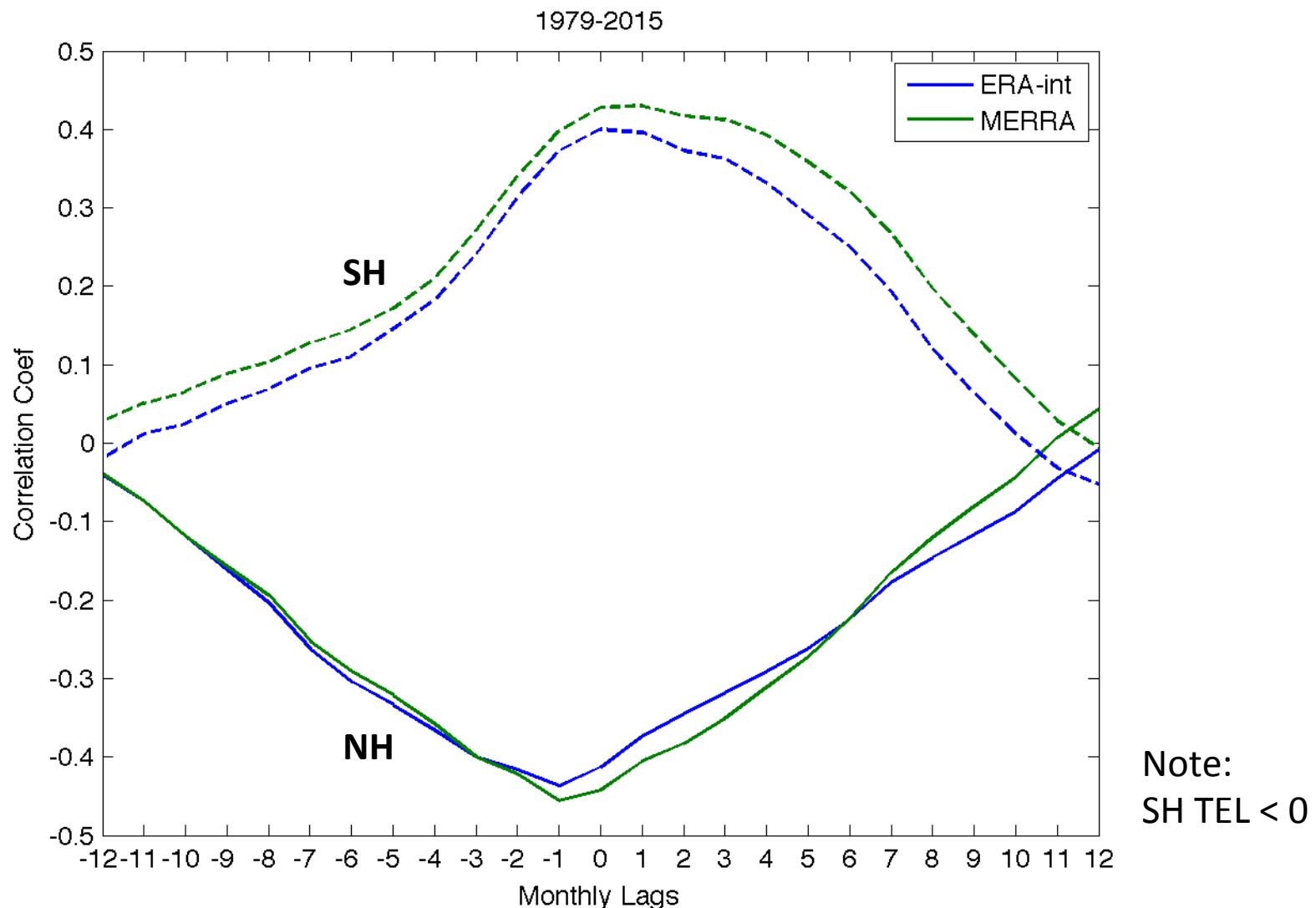
Recent Trends (Reanalyses & Models)



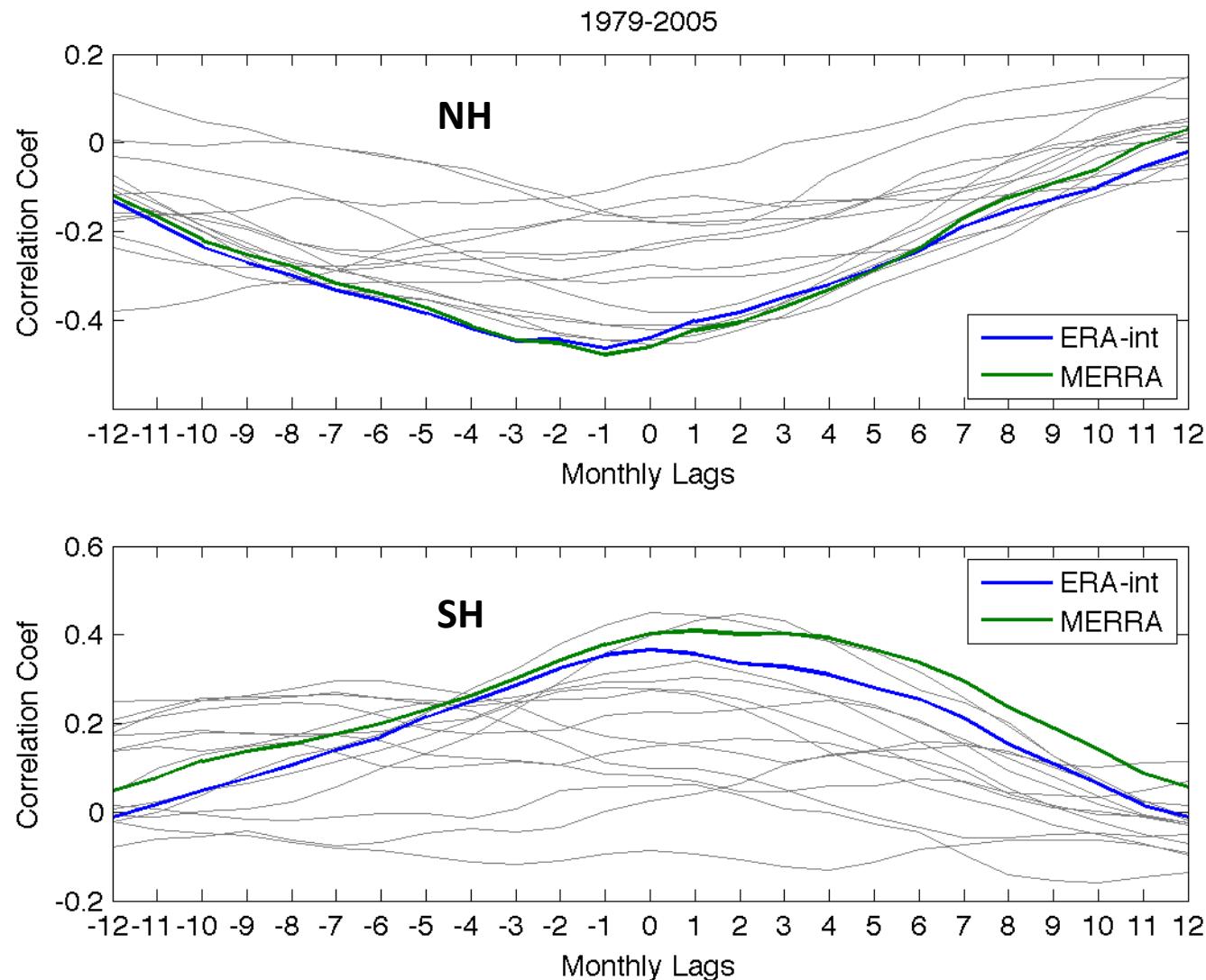
ENSO Corr (RO vs Reanalyses)



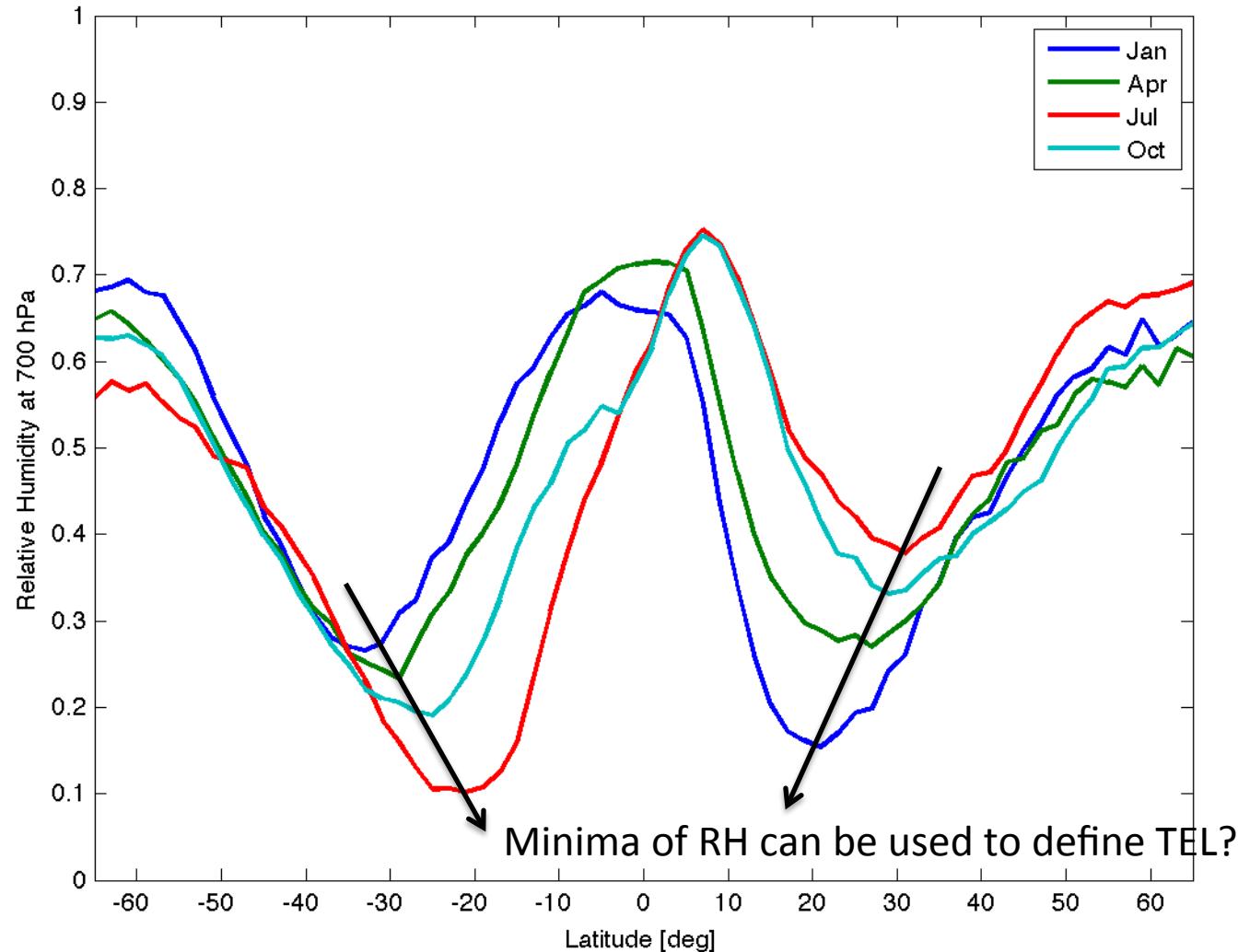
ENSO Corr (Reanalyses Only)



ENSO Corr (Reanalyses vs. Models)



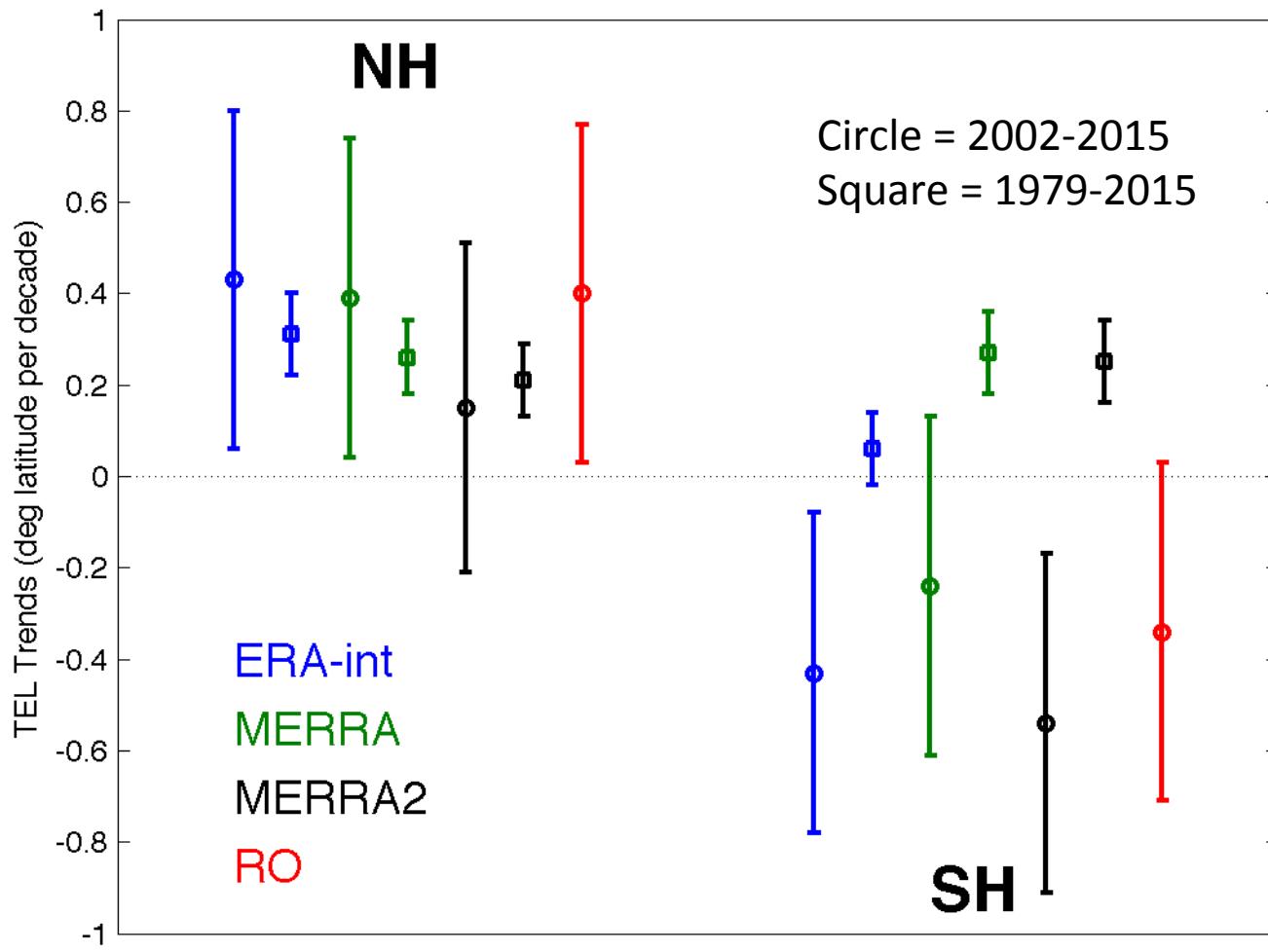
Tropospheric Humidity Metric



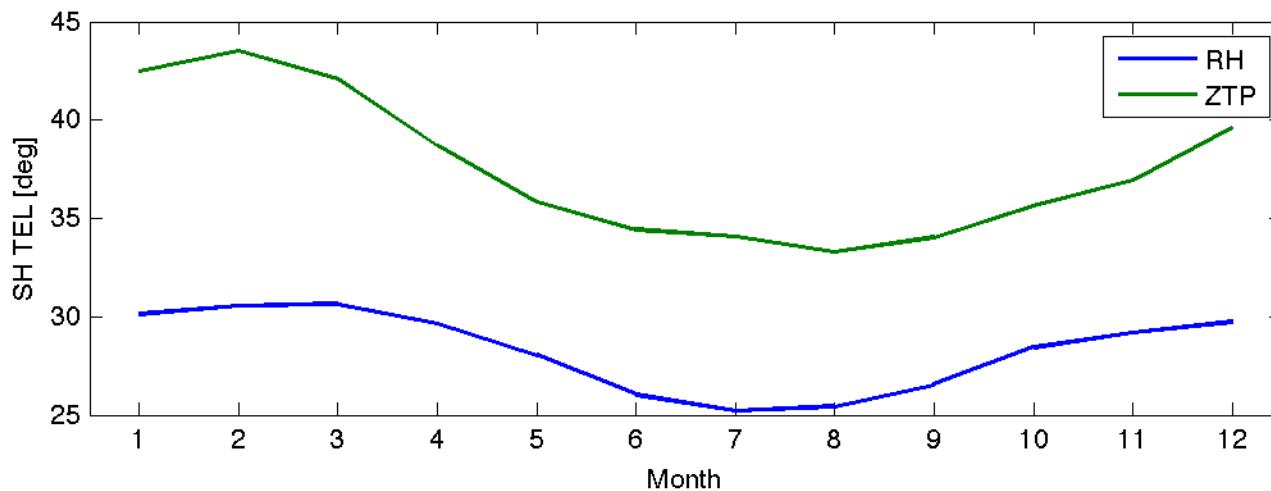
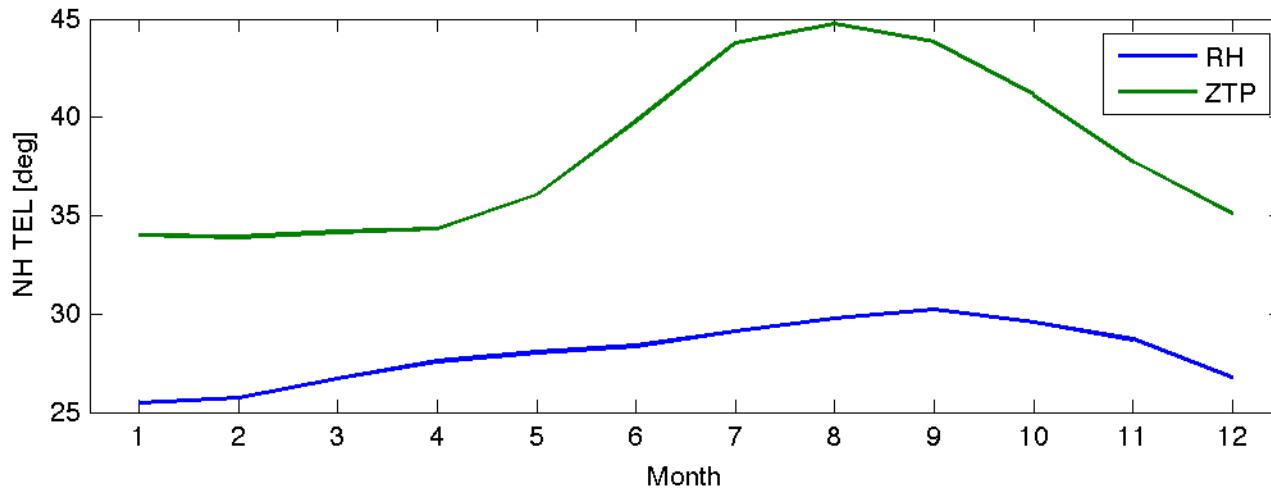
Summary

- During the RO era (2002–), there are good agreements (esp. NH) between RO and reanalyses.
 - Expansion in NH (~ 0.4 deg/decade)
 - Contraction in SH (~ 0.3 deg/decade)
- Notable disagreement between ERA-int and MERRA in SH after ~ 2001 . This is also true for MERRA2.
- Comparison with CCMVAL2:
 - Most models have smaller or no trends compared to reanalyses.
 - Interannual variability: most models have weaker correlations with ENSO despite being forced by observed SST.

BACKUPS



Seasonal Cycle



Monthly Anomalies

